An Upgrade of the Aeroheating Software "MINIVER"

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Contents

Introduction

- Background
  - Detailed computational modeling
    - CFD often used to create and execute computational domains
    - Increasing complexity when moving from 2D to 3D geometries
    - Computational time increased as finer grids are used (accuracy)
    - Strong tool, but takes time to set up and run
  - MINIVER
    - Uses theoretical and empirical correlations
    - Orders of magnitude faster to set up and run
    - Not as accurate as CFD, but gives reasonable estimations
- MINIVER's Drawbacks
  - Rigid command-line interface
  - Lackluster, unorganized documentation
  - No central control; multiple versions exist and have diverged

MINIVER Conversion: Background

- Special Study
  - Initiated by NASA KSC's Launch Services Program
  - Managed by a.i. solutions
  - Initially performed by Florida Institute of Technology
- First Development Phase
  - Written in C# (C-Sharp)
  - Updated user interface
  - Addition of helpful tools
  - Inclusion of basic CAD geometry editor
- MINIVER Version
  - Based on the 1983 upgrade by Engel, Praharaj, and Schmitz[1,2]
  - Code comments indicate upgrades in 2000, 2003
  - PREMIN and LANMIN upgraded, EXITS not carried over

MINIVER Conversion: PREMIN Module

- PREMIN Prompts
  - Whether to use English or Metric units for data input
  - What time intervals to use for data printout
  - Vehicle trajectory; manual input or file import
  - Which atmosphere model to use
  - Which heat transfer model to use
  - How to consider flow transition
  - Whether to consider crossflow or not
  - What type of flowfield and pressure environment to consider
  - If the surface geometry changes over time
  - How the wall temperature should be determined
  - How the user wants the output file to be generated

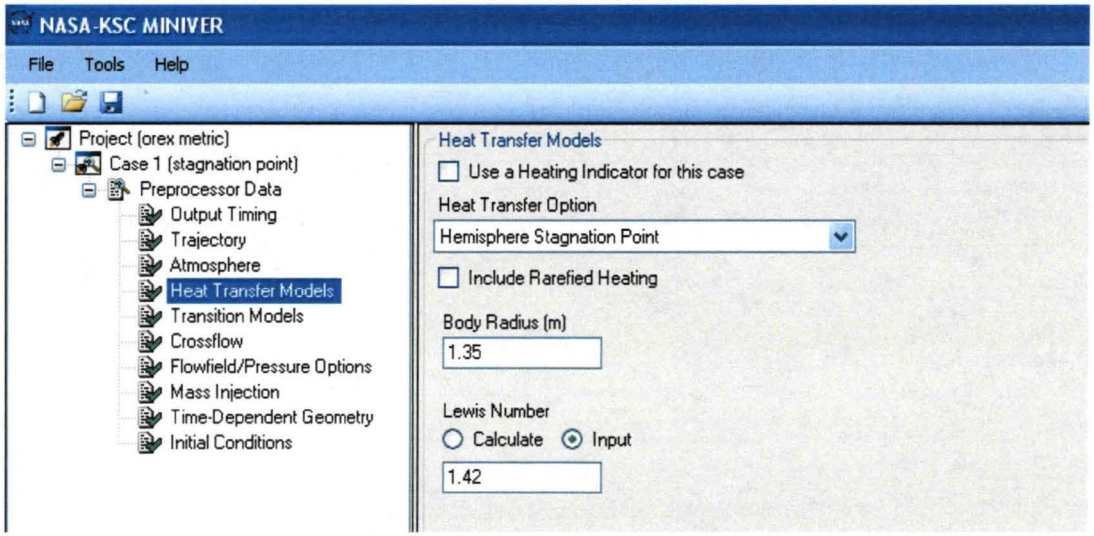
MINIVER Conversion: PREMIN Module

```
trajectory input is complete



     atmosphere data

 options     1.  1962 u.s. standard atmosphere
             2.  wind tunnel option
             3.  input atmospheric data(alt,t-inf,p-inf)
             4.  1963 patrick air force base atmosphere
             5.  1971 vandenberg reference atmosphere
             6.  1973 vandenberg hot day atmosphere
             7.  1973 vandenberg cold day atmosphere
             8.  1971 kennedy hot day atmosphere
             9.  1971 kennedy cold day atmosphere
            10.  1976 u.s. standard atmosphere

 option selected ?
10

 1976 u.s. standard atmosphere

 is this option correct ?
y



 do you want to run a heating indicator ?
n



      heat transfer method

 options     1.  hemisphere stagnation point
             2.  cato/johnson swept cylinder
             3.  eckert ref. enthalpy flat plate method
             4.  eckert/spaulding-chi flat plate method
             5.  boeing rho-mu flat plate method
             6.  beckwith/gallagher swept cylinder method
             7.  boeing rho-mu swept cylinder method
             8.  lees/detra-hidalgo hemisphere distribution
             9.  leeside orbiter heating
            10.  flap reattachment heating
            11.  fin-plate peak interference heating
            12.  brake payload impingement heating
```

Sample screenshot: Legacy PREMIN menu

MINIVER Conversion: PREMIN Module

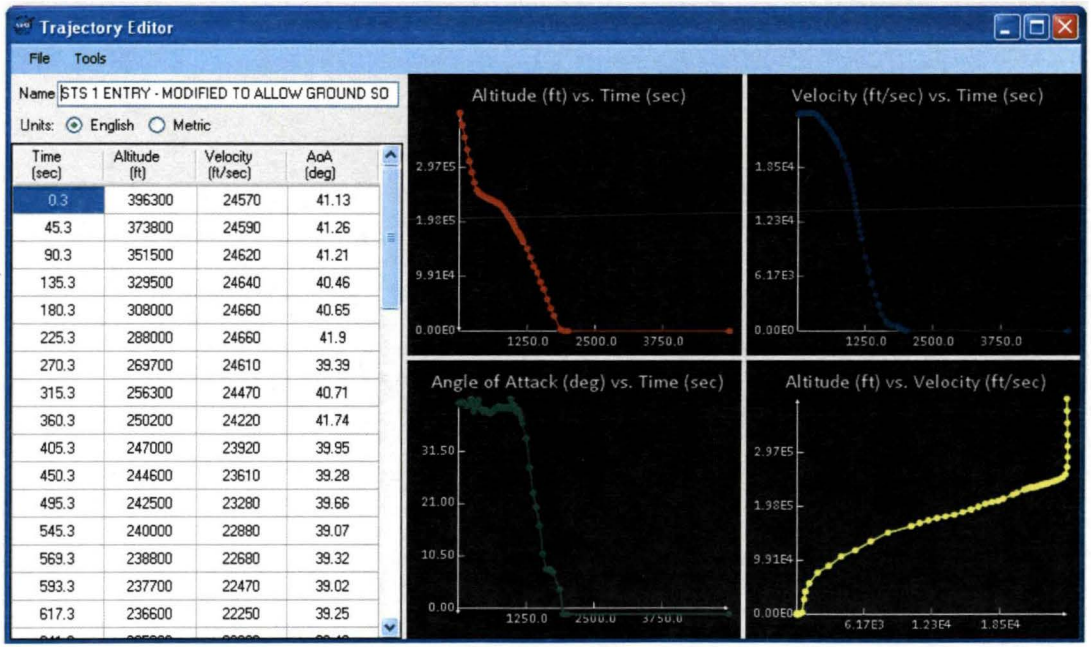
- New User Interface
  - PREMIN prompts collapsed into MINIVER 2.0 categories
  - Analysis revolves around a "Project" (e.g. launch vehicle)
  - Projects include "Cases" (e.g. body points)
  - Each case has preprocessor data that defines it



MINIVER 2.0 Main Screen

MINIVER Upgrades: Trajectory Editor

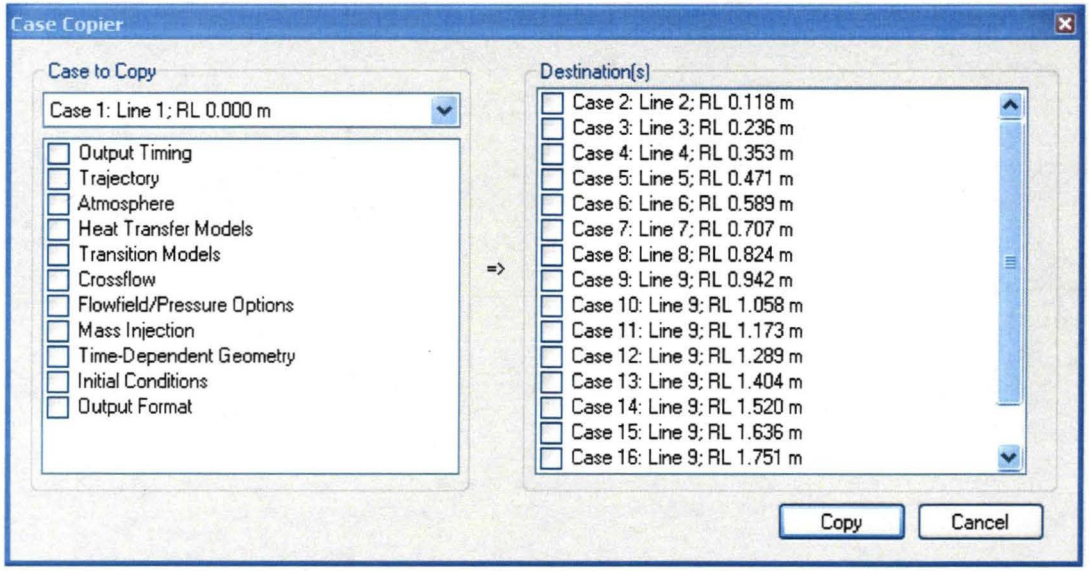
- New Tool: Trajectory Editor
  - Allows user to visualize trajectories
  - Runs within MINIVER or as a standalone program
  - New, open, edit, and save capabilities
  - Can import via Legacy format or custom delimited text files



Trajectory Editor

MINIVER Upgrades: Case Copier

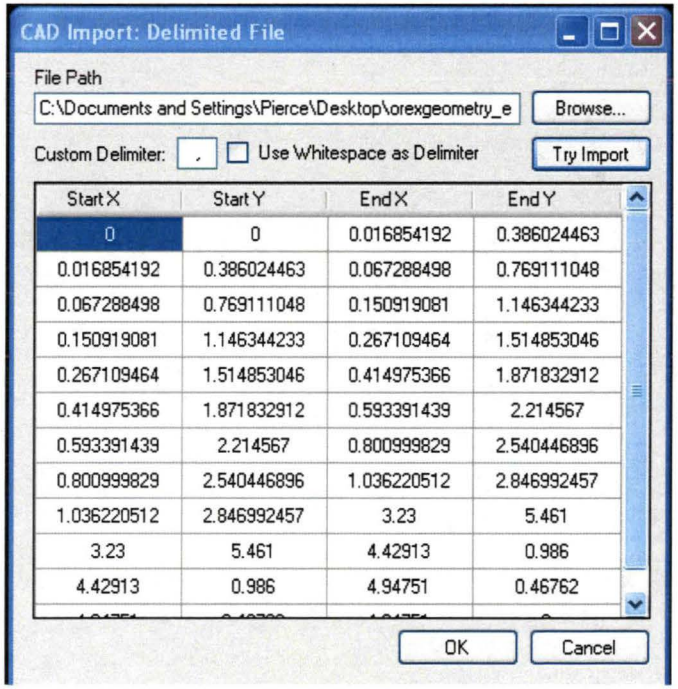
- New Tool: Case Copier
  - Allows quick copy from one case to many
  - Can start new cases with copied data
  - Useful for cases that share common data (e.g. trajectories)



Case Copier

MINIVER Upgrades: Delimited File Importer

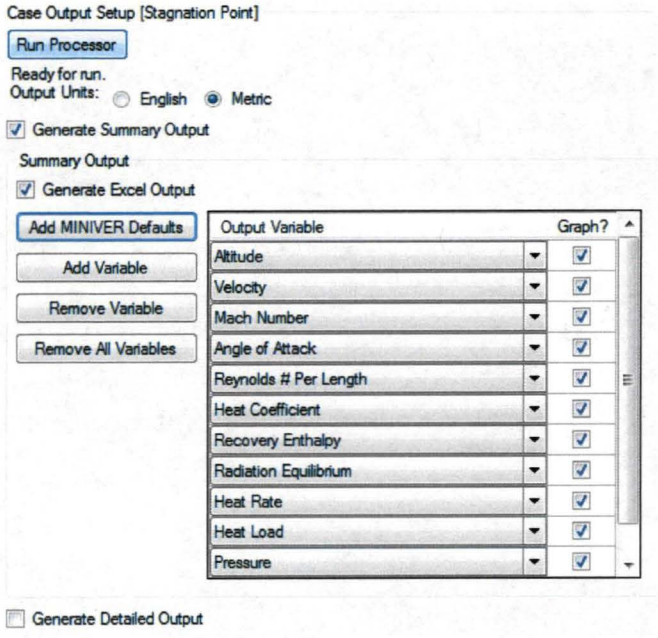
- New Tool: Delimited File Importer
  - Allows most text files to have data imported
  - Utilizes single character or whitespace for delimiting
  - Reusable code within MINIVER; constructor varies the output



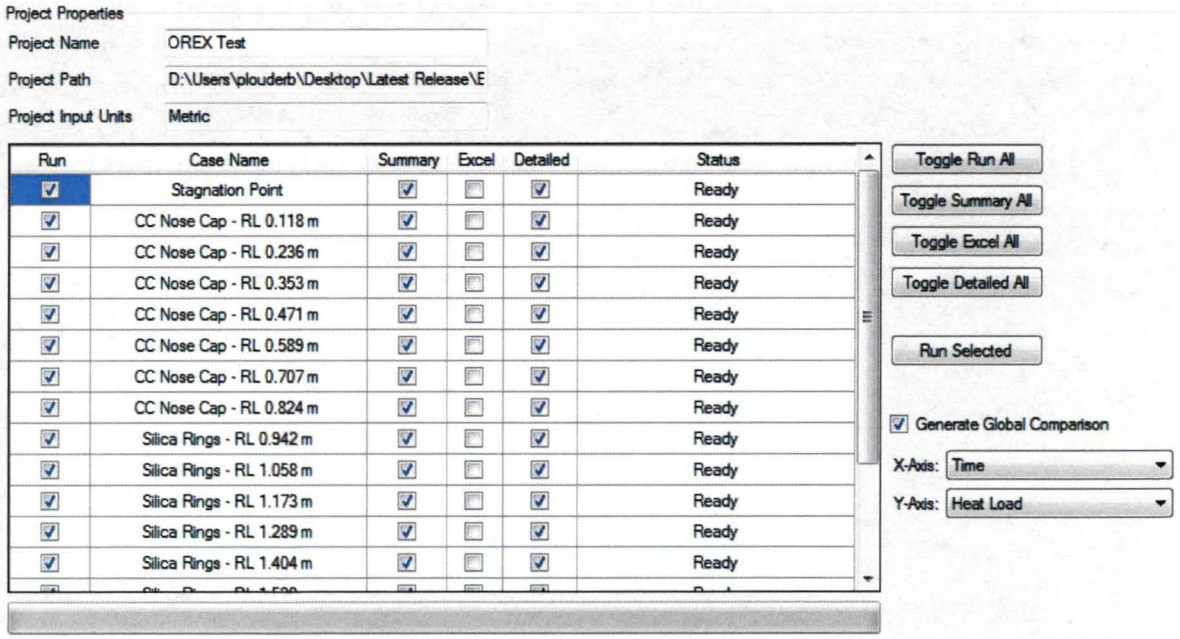
Delimited File Importer

MINIVER Conversion: LANMIN Module

- Code Conversion
  - Code initially left the same
  - Most conversion efforts involved replacing constructs like “go to”
  - LANMIN module is now a library within MINIVER 2.0
  - Processor logic can be executed case-by-case or project-wide



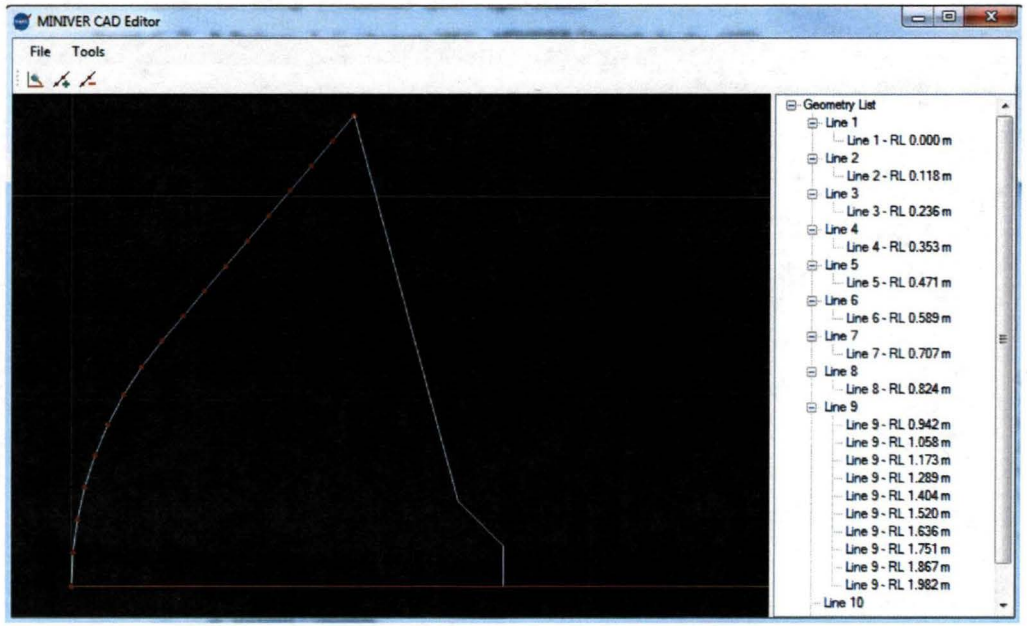
Single case processor setup



Project-wide case processor setup

MINIVER Upgrades: CAD Editor

- New Tool: CAD Editor
  - Imports basic 2D geometries from AutoCAD or delimited text
  - Points can be generated on lines to create MINIVER cases
  - Cumulative running lengths and local geometric angles are automatically calculated
  - Rectangular box select available to edit multiple points at once

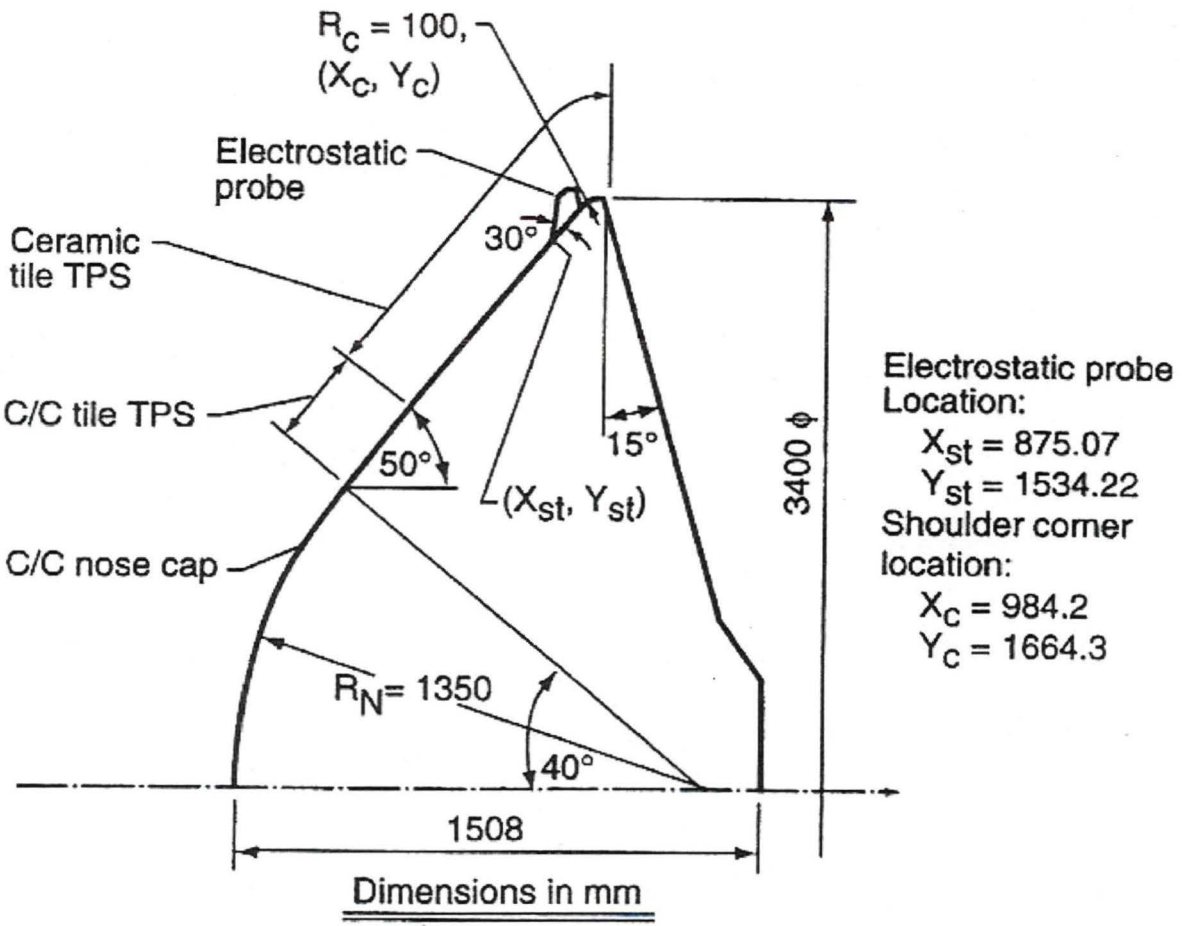


CAD Editor example with OREX geometry[3]

OREX Test Setup

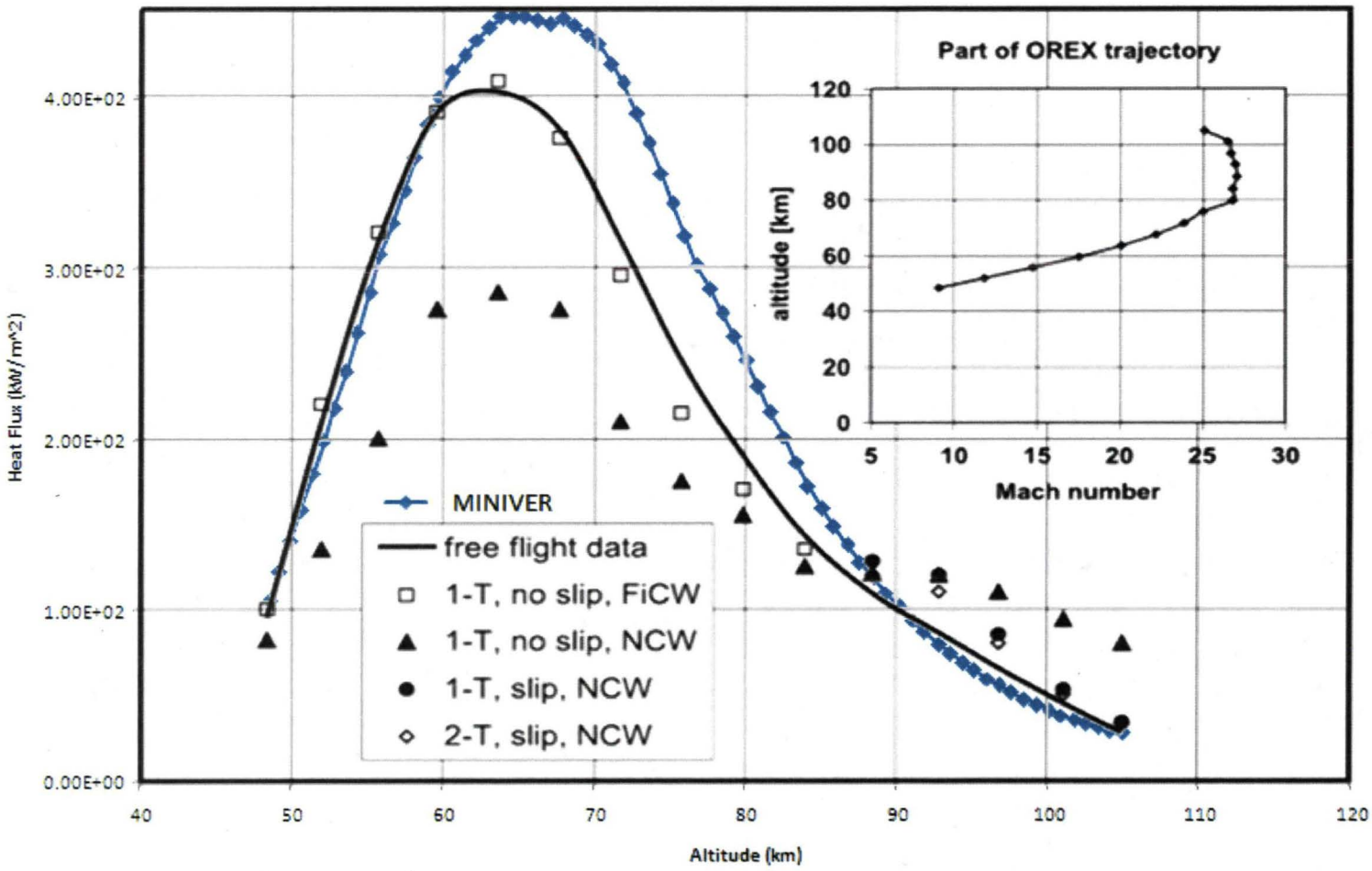
- Data from Gupta, Moss, and Price's paper[3]
- Flight data used for small subset of re-entry period
  - Trajectory
  - Geometry
  - Flight conditions
    - 1962 U.S. Standard Atmosphere approximation
    - Hemisphere Stagnation Point option at stagnation point
    - Lees/Detra/Hidalgo Hemisphere option on the spherical nose cap
    - Eckert Reference Enthalpy Flat Plate for the rest of the forebody
      - Mangler transformations used to convert from flat plate to cone
- Experimental data was only taken at stagnation point

OREX Geometry



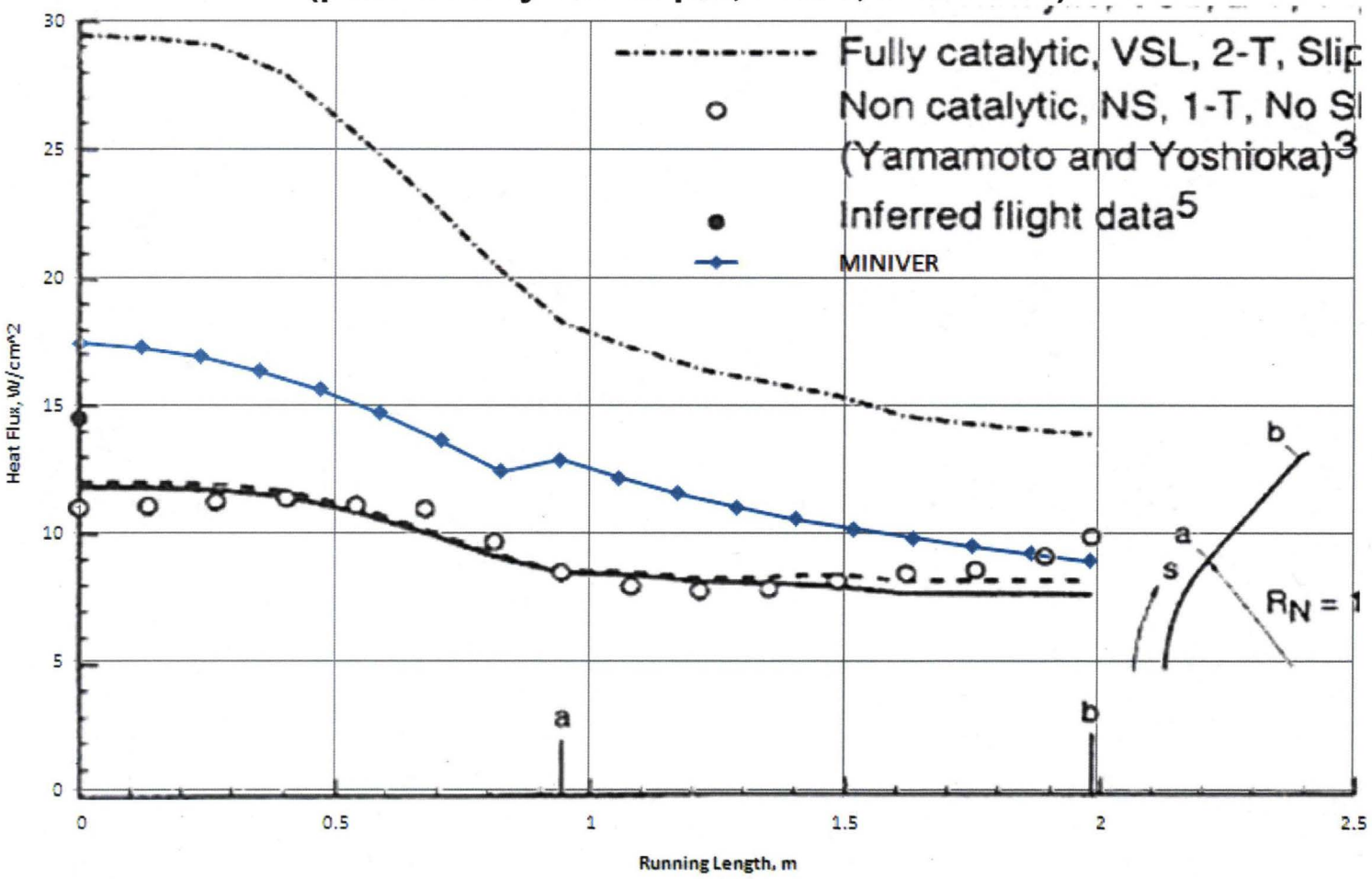
OREX Results

OREX Stagnation Point Flight Data Comparison (plot overlay via Hirschel & Weiland)[4]



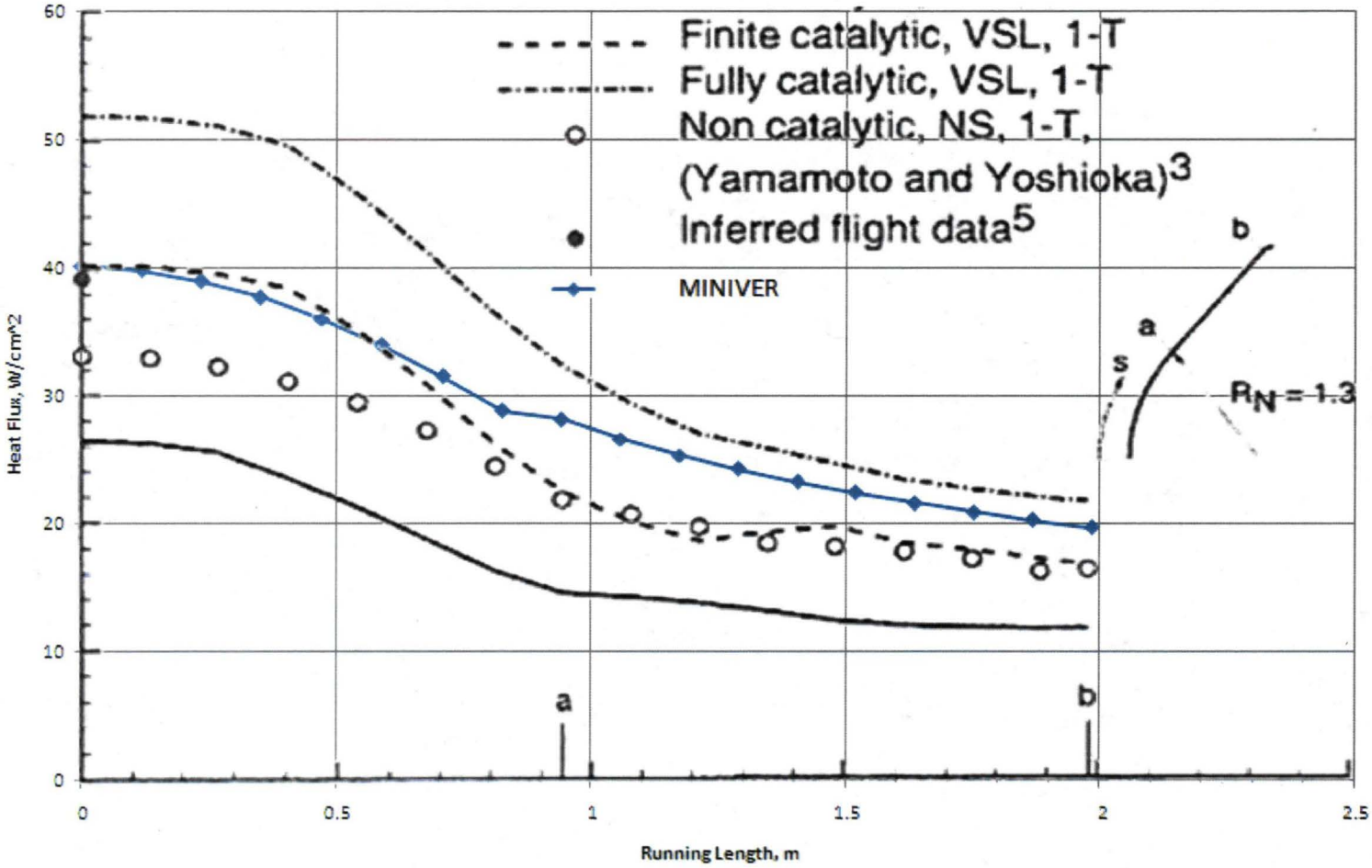
OREX Results

OREX forebody heat rate at 84.01 km; MINIVER comparison to VSL calculations (plot overlay via Gupta, Moss, and Price)[3]



OREX Results

OREX forebody heat rate at 59.60 km; MINIVER comparison to VSL calculations (plot overlay via Gupta, Moss, and Price)[3]



Conclusions and Future Work

- MINIVER updates are an ongoing effort
  - New interface provides fast, intuitive workflows for users
  - Added utilities assist in performing setup tasks
  - Results demonstrate effectiveness for fast estimation
  - MINIVER is source controlled and developed at KSC
- Future Work
  - Next phase will explore links to SINDA and Thermal Desktop
  - New features will be added based on user need
  - Would like to explore converging MINIVER from other centers
  - Experimenting with third party and open source libraries to improve the MINIVER's look, feel, and capabilities

Acknowledgement

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[b] Associate Department Head, Associate Professor, Mechanical & Aerospace Engineering, Florida Institute of Technology
[c] Associate Professor, Mechanical & Aerospace Engineering, Florida Institute of Technology

Questions?

References

1. Engel, C.D., and Praharaj, S.C. (August 1983). *MINIVER Upgrade for the AVID System, Vol 1: LANMIN User's Manual.* NASA CR-172212.
2. Engel, C.D., and Schmitz, C.P. (August 1983). *MINIVER Upgrade for the AVID System, Vol 2: LANMIN Input Guide.* NASA CR-172213.
3. Gupta, R.N., Moss, J.N., and Price, J.M. (1997). Assessment of Thermochemical Nonequilibrium and Slip Effects for Orbital Re-Entry Experiment. *Journal of Thermophysics and Heat Transfer, 11*(4)
4. Hirschel, E. H., and Weiland, C. *Selected Aerothermodynamic Design Problems of Hypersonic Flight Vehicles.*

Backup Slides

Modern Summary

- Provides summary of all case data set so far

Preprocessor Data

Modern Summary (Verbose Format)

Data Entry	Data Value
Output Timing	
Time 0	0
Delta Time 0	5
Time 1	100
Delta Time 1	100
Time 2	1000
Delta Time 2	0
Time 3	0
Trajectory	
Trajectory Name	STS 1 ENTRY - MODIFIED TO ALLOW GROUND SOAKBACK TIME
Trajectory Data Point 1	Time: 0.1, Altitude: 396300, Velocity: 24570, Angle of Attack: 41.13
Trajectory Data Point 2	Time: 45.3, Altitude: 373800, Velocity: 24590, Angle of Attack: 41.26
Trajectory Data Point 3	Time: 90.3, Altitude: 351500, Velocity: 24620, Angle of Attack: 41.21

Preprocessor Summary

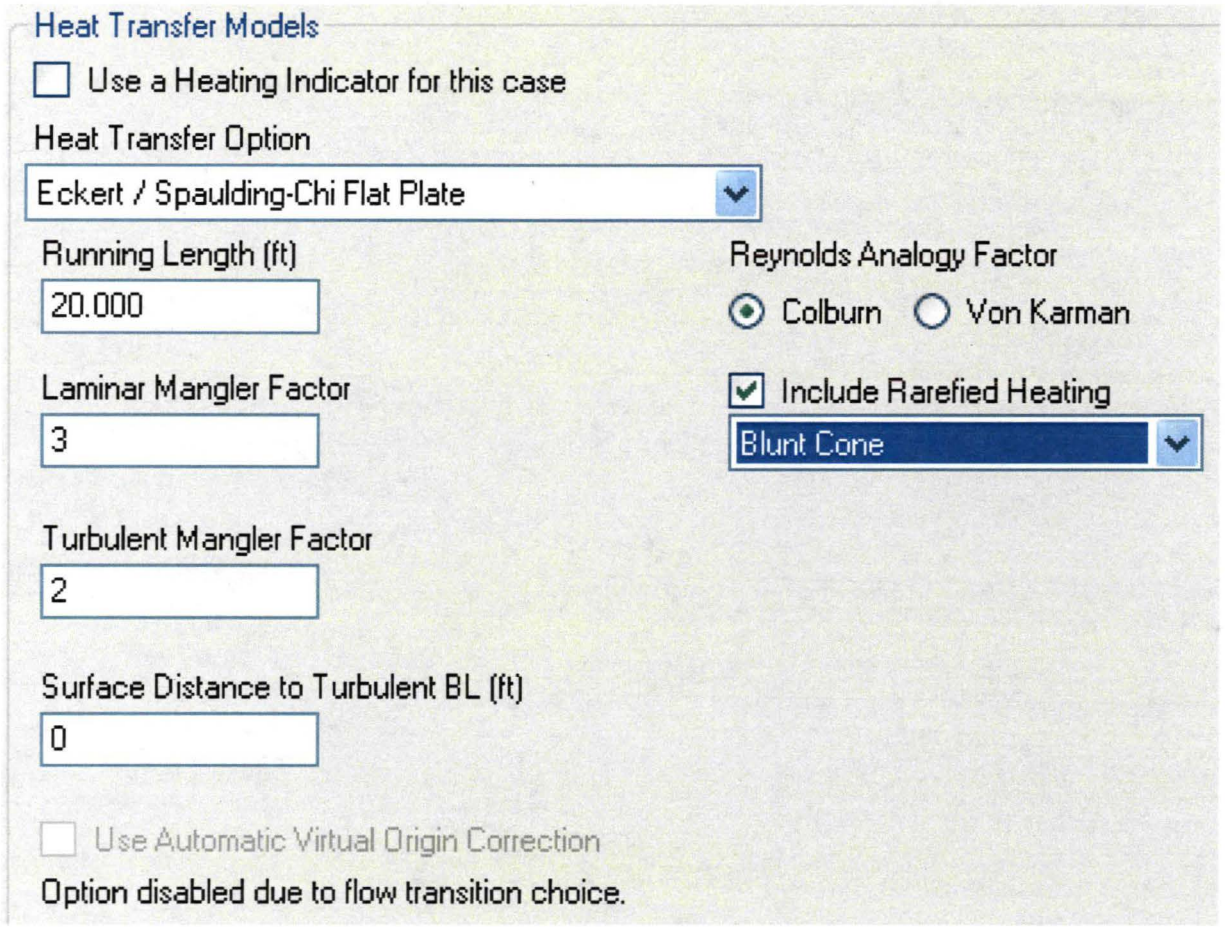
- Provides Legacy (W Array) summary of all data entered

Preprocessor Data

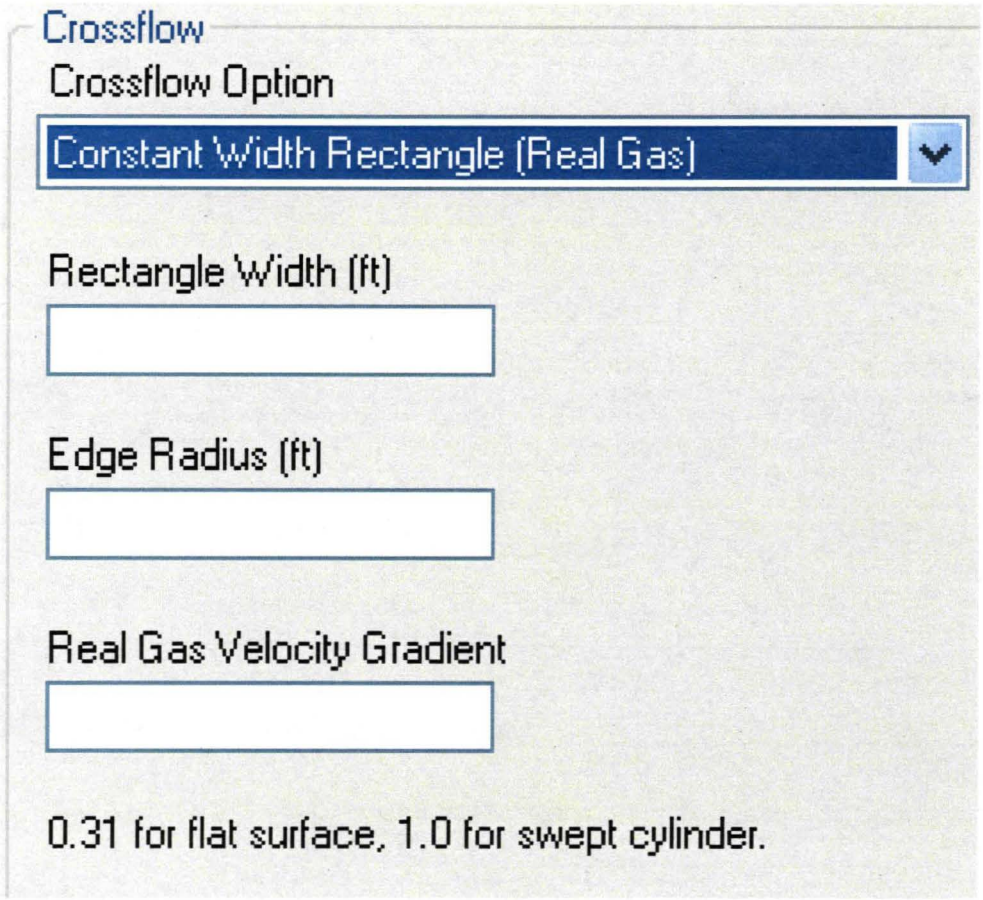
Legacy Summary (W Array Format)

W Array Index	W Array Value
w[1]	0
w[2]	5
w[3]	100
w[4]	100
w[5]	1000
w[6]	0
w[7]	0
w[8]	0
w[9]	0
w[10]	0
w[11]	0
w[12]	0
w[13]	0
w[14]	0
w[15]	0
w[16]	0
w[17]	0
w[18]	0
w[19]	0
w[20]	0

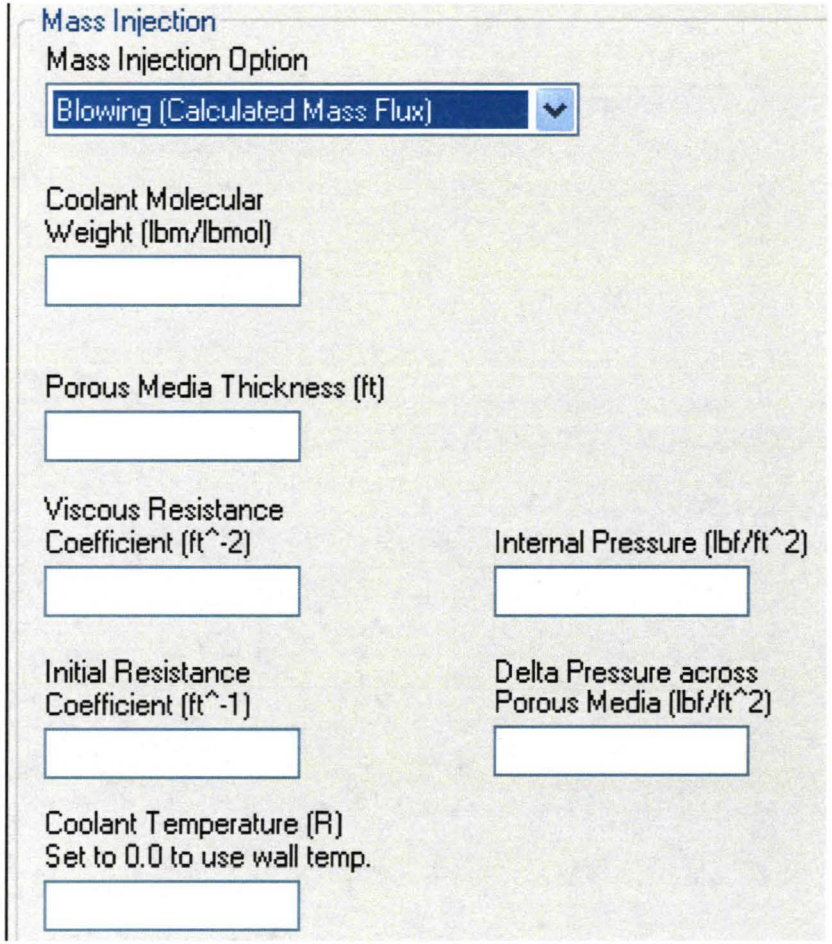
Heat Transfer Model Example



Crossflow Option Example



Mass Injection Option Example



CAD Editor Point Adding